See: Educational Studies 35(3) 311-321
Running head: *Knowledge development at the time of use*

Knowledge development at the time of use: a problem-based approach to lesson-planning in primary teacher training in a low knowledge, low skill context.

Douglas P. Newton* and Lynn D. Newton

School of Education, Durham University, UK

*Corresponding author. School of Education, Leazes Road, Durham, DH1 1TA, UK.

Email: D.P. Newton@durham.ac.uk

Abstract

Primary school teachers generally have to teach several subjects. Their training, however, is often fairly short and it is tempting to force-feed them with everything they need to know to teach these subjects. It is more realistic to accept that a short course cannot do everything. Instead, it would be better to equip these students with skills that help them cope when their initial knowledge is weak. This study describes a problem based learning approach to skill development in science lesson planning where subject knowledge was initially weak. It examines student-teacher confidence in and satisfaction with this planning, motivation and feelings about collaborative work. Advice is offered on adopting a PBL approach for developing lesson planning skills.

Keywords: *Primary teacher training; Problem-based learning; Science lesson planning.*

Introduction

In England, most who want to teach in the primary school (children aged 5 to 11 years) train on a post-graduate course lasting roughly one academic year. A teacher of young children usually has to teach several subjects, including those where the teacher's initial knowledge and interest may be relatively low (Allen & Shaw, 1990; Bennett & Carré, 1993; Edwards & Ogden, 1998). Science can be one of these. Many primary school student-teachers have not studied science themselves beyond the age of sixteen years and their initial knowledge is often insecure (OECD, 2005). As with teacher training in some other countries (for example, Hope (1999)), time to refresh and develop this knowledge is short. Nevertheless, these students will have to plan sound and effective science lessons. In the USA, Hiebert et al. (2003) have described a similar problem when training teachers to teach mathematics. The solution, they argue, is to accept the limitations of such courses and, instead of force-feeding students, give them tools to use to solve the problem as the need arises. This has the additional, long-term benefit of equipping teachers to cope with expectations that change over time (Savin-Baden, 2000; Cheng et al., 2002; Tan, 2001; OECD, 2005).

In primary school teacher training course in the nUK, science education is one strand running in parallel with the other 'core' subjects of English and mathematics education. Shorter strands provide training in religious education and the 'foundation' subjects of history, geography, art, music, design and technology and physical education. Training in the teaching of these subjects and generic matters spans twenty weeks, the remaining time being for student teaching practice in schools. Flexibility is limited by the government's Training and Development Agency's requirements.

Previously, the science strand at Durham comprised lectures on aspects of science education followed by workshops to develop pedagogical and subject knowledge and supported study sessions to extend subject knowledge. Nevertheless, it was evident that a significant number of students expressed a lack of confidence in planning science lessons and found it to be excessively time consuming, particularly for topics not covered in the workshops. Given that such students must plan lessons for topics where their subject knowledge is initially relatively weak, we sought an approach which might give them skills, enhance their confidence and make the time spent acceptable to them.

Having a strong knowledge of science does not, in itself, make a good science teacher. In fact, Kind (in press) has shown that those who begin with a relatively weak knowledge of a topic can produce good science lessons. A student teacher who acquires that knowledge at the time it is needed tends to process it with the learner in mind, anticipates learning difficulties and pays attention to ways of overcoming them. Conversely, those already familiar with the topic may fail to anticipate the difficulties in understanding it for the first time. On this basis, student teachers, initially without a lot of subject knowledge and faced with the problem of planning a lesson, may construct a useful blend of subject and pedagogical knowledge and represent the content for the children in meaningful ways. (Heywood (2007) has explored this concept further in a related context). In practice, Kind found that student teachers were not equally skilled at planning lessons from a low knowledge starting point. They could, therefore, benefit from opportunities to practise the skills and, in the process, gain confidence and make the process more efficient. Problem-based learning seemed to have the potential to provide students with these skills.

Problem-based learning

In problem-based learning (PBL), students are given a realistic problem to solve and generally address it without prior instruction (Schwartz et al., 2001). The approach was initially developed to train medical students at McMasters University, Ontario (Barrows & Tamblyn, 1977) but it has also found application elsewhere when what is to be learned can be cast in the form of a realistic problem (e.g. Mackinnon, 2006; Pepper, 2008). The students usually work in groups with some tutor support for part of the time. The tutor's role is to help students understand the problem and its scope and facilitate ways of working but not to provide answers to the problem. Resources such as books and access to the Internet and to the library are usually required. The promise of PBL lies in the way it can mirror professional action, motivate students, produce durable, meaningful learning, enhance the ability to use resources, have students cross the theory – practice divide, integrate learning and develop the skills of the 'lifelong learner' (Engel, 1991; Vernon & Blake, 1993; Maudsley, 1999; Savin-Baden, 2000; Schwartz et al., 2001; Newman, 2003; Beringer, 2007). Reports of PBL in teacher training are relatively rare but McPhee (2002), working with practising teachers interested in school management, found PBL to stimulate thought and to be motivating.

Given this, the attraction of PBL is considerable but it has limitations. Studies have also shown the approach can produce a tendency to reason backwards and leave gaps in knowledge as only that needed to solve the problem is studied (Albanese & Mitchell, 1993). Nor does it always lead to more knowledge or better practice than other approaches, at least in medicine (Newman, 2003) and not everyone likes working in a group (Maudsley et al., 2007). At the same time, the tutor should not be entirely ignored. Some may produce better learning with an approach they find more satisfying and which lets them interact differently with students (Bailey, 2008). Students may also lose the benefits of learning from an inspirational tutor (Davis & Harden, 1998; Mackinnon, 2006). Consequently, Berkson (1993) and Colliver (2000) concluded that PBL is no more effective than other ways of learning. This conclusion is probably too sweeping. A given approach may suit one end better than another. If, for instance, knowledge must to be gap-free or will be used to reason forwards, PBL may not be a good choice. But it could be a good choice for developing problem solving skills, such as planning a science lesson when initial subject knowledge is weak, as it obliges the student to engage directly with and to practise solving the very problem they will meet as teachers. Reports also indicate it to be motivating and to foster collaborative work.

The PBL approach

On the training course, there was a supported self-study slot where a workbook was used to develop subject knowledge. Six science lesson planning problems were constructed to replace this work. The science topics involved were not addressed in other parts of the course. As McPhee reported that some teachers did not like group work, student autonomy was extended to allow them to work in groups (four to six students) or to work alone. Most chose to work in groups but everyone was expected to present a written, personal solution to each problem to reflect practices in schools more closely. Three tutors (not the authors) supported the cohort of 75 students (in three groups of roughly equal size) and worked in rotation with each group. Their role was to help the students grasp the nature of the problems and facilitate group work and access to resources. The resources for each group comprised children's textbooks on science, books for teachers, elementary books on subject knowledge, government documents setting out and illustrating expectations in science in the primary school, computers linked to the Internet, and access to an education library and school book resource centre. Each problem was to be completed in two weeks, partly in the allocated, one-hour slots and partly in the students' own time. It was then submitted and assessed by the tutors who provided written feedback on each student's skills in collecting, selecting and collating relevant materials and on the quality of the lesson(s) produced. Principles of good practice in instructional design for adults were applied, such as, making the relevance of the task explicit, allowing autonomy in approach, making the level of demand progressively greater, and providing early feedback (Bohlin et al., 1993-4).

The problems

The first problem had students' attend directly to their skills of collecting, selecting and ordering information for a lesson plan. The science topic was a simple one but many students would need to refresh or supplement their knowledge. In the first one-hour session, the students' explored the resources and were warned that some may not be good teaching models without adaptation. In the second one-hour session, one week later, attention was drawn to a pro-forma on which solutions were to be presented. The terms used were explained then the students focused largely on fixing and sequencing their lesson content.

Problem 1: Science planning which works for you.

'You have a younger Key Stage 2 class (8 to 9 years old) You have to teach them an introductory lesson about Life Cycles but you can recall very little about life cycles, you have no idea how to introduce the lesson, how to explain what life cycles are, what kinds of words to use, or what activities the children might do.

Your task is to solve the problem. It has two parts:

- Find a straightforward way of collecting the information you need to teach the science lesson;
- Use it to plan the lesson.

Remember: The aim is to construct a way of science lesson planning which works for you.'

Subsequent problems provided opportunities for students to practise finding, choosing and adapting relevant subject knowledge. The second problem asked students to plan a lesson to address an unexpected misconception revealed by the children. Again, the tutor clarified the problem and helped the students discuss the ideas which might underpin the children's thoughts. The students drew on the resources and gathered ideas for teaching about gravity. Nothing in these resources provided a direct solution but discussion helped to formulate thoughts. These were presented on a pro-forma like that provided for Problem 1. In this case, however, they were also asked to state what the parts of their approach were intended to achieve.

Problem 2: Working with misconceptions.

> 'In a topic on Forces, you have to do work on Gravity. As a part of that, you have the children drop objects and find ways of slowing down their fall, as with parachutes (Lesson 1). You cleverly include an investigation in which the children have to find which kind of parachute works best: square, round, or triangular (Lesson 2). In the plenary session, you engage the children in a science conversation to develop their language skills and to explore their grasp of gravity. This is what happened (T = teacher):
>
> T: So, why do things fall down?
>
> Donald: Gravity. It pulls things down.
>
> T: That's good! Does gravity pull everything down?
>
> Sacha: No, not everything. I've seen feathers. They just go up!
>
> Pauline: And so do the fuzzy tops on dandelions. They just float away!
>
> The problem is that you will need to address this misconception in your next lesson. Plan a lesson to do so.'

In one of the generic sessions of the course, the students were urged to avoid the temptation to focus only on teaching facts and neglect understanding, whatever the subject. Problem 3 comprised a short transcript of a lesson on Plants in which the teacher fired only factual questions at the children and rehearsed their responses for quick recall. The students were asked to prepare a lesson on the same topic which addressed understanding. Like the one provided, this was to be presented in the form of a transcript. Tutors helped students give attention to what understanding in science might mean. Problem 4 was to practise science lesson planning for diverse abilities. Here, outline plans for two lessons were provided and the students were to differentiate them to suit more and less able children. To accompany these, a test of learning was also to be compiled.

Problem 4: Personalising lessons.

'Children are different: some catch on quickly and succeed with ease, others are slower and find it a bit difficult. You must be able to tune your teaching to suit different needs. Your new class comprises 34 children. You are told that most seem to like doing science but six boys and four girls have difficulty with it. On the other hand, four boys and five girls are very good. You must teach this class about Materials and their Properties. The first two lessons are on Dissolving Things**.** Tune the lessons to meet the needs of these children and prepare to assess their knowledge and understanding in a way which recognises the children have different abilities.'

The previous problem introduced the students to two sequential lessons. Problem 5 had them plan for longer sequences and also plan to tie learning to work done in other subjects. If these plans were described in detail, the demand would be prohibitive, given that the students had other subjects to study, so these were to be presented in an abbreviated form.

Problem 5: A lesson sequence.

'You have to teach Electricity for either a Key Stage 1 or a Key Stage 2 class. This needs a progressive sequence of lessons. You are also expected to see what you might do in connection with Electricity in other areas of the curriculum in order to make learning more secure.'

The final problem returned to the planning of one lesson. On this occasion, new pedagogical demands were introduced, to do with 'engaging science teaching'. This was described as involving the consideration of *instruction* (a provision for interest and understanding) and *relationships* (a consideration of teacher enthusiasm, the maintenance of an atmosphere conducive to learning, and support for individual children) (Darby, 2005). Here, the students were expected to research the science topic and incorporate additional, new pedagogical concerns, much as they might be expected to do at times of curriculum change in schools.

Problem 6: Engaging science teaching.

'The problem with some teachers is that they can't make science lessons engaging. An engaging lesson is one where children become engrossed, interested, make progress, and finish with satisfaction. It is hard to make every lesson engaging but when you achieve it, you will find it is very rewarding and want more.'

Plan an engaging lesson for a Key Stage 1 or 2 class for the topic of Sound or Light or Characteristics of Life, or Ourselves, or for the topic you have to teach in school.'

The term PBL has been used to describe a variety of approaches (Boud & Feletti, 1996). Boud and Feletti describe essential features of PBL, such as the early presentation of the problem, students with autonomy and a tutor who facilitates but does not solve the problem. As these features can vary, approaches may be described as more or less problem-based. Barrows (1986) produced a taxonomy to score approaches according to variations in such features. For instance, at one end of the scale is the approach where students have to analyse the problem, identify, locate, acquire and understand what they need to know, and synthesise a solution themselves, without the benefit of direct instruction on the topic. This calls for a prolonged and detailed engagement which fosters learning. At the other end of the scale is the approach in which the 'problem' is presented as a case study to illustrate an exposition of a topic. Now the student can be a more passive learner and may fail to engage with the subject in ways which produce adequate learning (Newton, 2000). The tasks described above, the manner of their presentation, and the nature of the tutors' support made this element of the course strongly problem-based, as described by Barrows and by Boud and Feletti.

Following the advice of Lynn (1999), notes on the problems were provided for the tutors. These comprised a brief abstract of each problem, teaching and learning objectives, matters to bring to the students' attention or to discuss, possible student questions, pitfalls or difficulties and how to respond to them, and the scope of the solutions expected. There were also fortnightly meetings with the tutors to review progress and look ahead.

Assessment of the solutions

Approaches which produce large quantities of paperwork for assessment are a problem for busy tutors. For that reason, single sheet pro-formas focused attention on what was to be assessed and allowed the tutor to assess some aspects quickly. For instance, the presence or absence of some aspect of a lesson might be indicated by a tick or its quality indicated by ticking a box on a scale of 0 to 5. Nevertheless, a space to provide an overall comment and to offer advice on improvement was always provided for each problem. For example, a student might be advised to reconsider the length of a lesson or make the proposed discourse more child-friendly.

In summary, the main aim of the PBL approach here was to help student teachers acquire skills of efficient lesson planning when initial science knowledge was low. Six problems were provided to support the process. The students were free to work in groups or alone. Tutors did not provide solutions but clarified matters, facilitated the process and provided prompt feedback. It was anticipated that the process would generate learning of science relating to the topics concerned and this was seen as a bonus rather than a central aim. Given the earlier findings, it was also anticipated that students would find the PBL element of the course motivating.

The student teachers

As this was a post-graduate course, the 75 students had bachelor degrees. Only four were science-centred. The largest group related to languages (English and modern foreign languages) followed by those to do with history, geography and theology, the social sciences and psychology, education studies, sport and then low numbers of diverse others. The overwhelming majority of students (95%) did not have what might be described as a biological or physical science education to degree level.

Evaluation

The main aim was to foster confidence in science lesson planning and make the time it takes more acceptable to the students. PBL may also enhance motivation and promote collaborative work. Data were collected to inform discussion about these. Although tutors' opinions are subjective, they are also included here as they show their response to the strand and draw attention to matters which may need further consideration by others who wish to adopt an approach of this kind.

The students' views

At the start and near the end of the PBL element, the students were asked to rate their confidence in planning a lesson to teach a science topic they knew little about. (Responses were marked on a 0 to 9 scale where 0 indicated 'not at all' and 9 implied 'easily', 'considerably', or 'very much', according to the question.) The average score increased from 3.24 at the outset to 6.49 (a difference that was statistically significant, t-test, $p<0.0001$). The students were also asked to rate the extent to which the PBL element helped them plan lessons in a length of time they found to be acceptable while on teaching practice in schools, again on the 0-9 scale. The mean score was, on average, 5.94. Similarly, the opportunity to work collaboratively was rated at 6.01 while the extent to which the approach was found motivating received a mean rating of 4.99.

At the same time, three focus groups, each of about twelve students, were drawn at random from the cohort. One of the authors led the groups and asked for reasons for the observed scores. There was agreement that the PBL experience had increased lesson planning skills and made planning easier. This had reduced apprehension and increased confidence. In the previous year, some students had commented that science lesson planning took a lot of time. These students felt that the experience of PBL had made their planning more efficient and speedy. Some students on school placement found themselves having to fit into and use the schools' existing plans. They said that PBL had helped them see weaknesses and opportunities in these ready-made, school-prepared plans. Many found that collaboration had allowed them to 'bounce ideas off each other', 'share experiences', and 'build up ideas'. They also felt they benefited by seeing that others shared the same concerns. Some, however, said they worked better alone, using books and the Internet. Nevertheless, these acknowledged that this simply reflected different preferences in ways of learning. There was general agreement that the practical relevance of the PBL strand was real and evident and this made it worthwhile. They also found the regular, constructive feedback to be helpful. A concluding comment was, 'I just want to say I had no knowledge of science but feel more confident because of this.'

There were also students' course evaluations, submitted anonymously. Typical comments were, 'Lesson planning is a really good idea' and 'I find the tasks extremely helpful in preparing me for planning'. Given that this is only one part of an intensive course, one student wrote, 'The fortnightly problems we complete haven't been too strenuous'. Another wrote, 'I like having individual work to do and the amount does not overburden us.' Nevertheless, PBL did not suit everyone and one student felt that watching an experienced tutor plan would have been ‘more useful’. Favourable comments, however, were far more common.

The course tutors’ views.

Three tutors, all experts on science lesson planning, supported the PBL element and were interviewed individually by one of the authors. All tutors expressed the opinion that working on the problems helped the students develop their science lesson planning skills. They referred to a ‘steady refinement’ in the students’ skills in using the resources and in producing plans. They all agreed that the students showed a progressive improvement in their ability to select suitable content and one spontaneously added that the students’ confidence had increased. Furthermore, they felt there was evidence of a growing grasp of the nature of an effective lesson and how to produce one. For instance, one tutor cited a student who said, ‘Before I would have . . . But now I would . . .’ When asked about motivation, all had found that the students applied themselves to the task unprompted and engaged with them willingly. One added that the PBL element was obviously relevant and gave the sessions a clear purpose. Regarding the ease with which the solutions were assessed, pro-formas were found to simplify the task so that it was not too onerous. One added that ‘even if it took longer, it was worth doing’. Taking a broader perspective of the PBL element, the tutors were very positive. It was seen as ‘a major step forward’ and ‘more valuable’ than what was done before. At the same time, tutors felt some attention needed to be given to a small number of students whose submissions were considered to be unsatisfactory. The course leader also held meetings with the tutors after each problem. To begin with, tutors expressed some difficulty in resisting the temptation to point students towards specific solutions, particularly when students tried to elicit solutions from them. The tutors' assessments tended to focus on qualities of the product such as the scientific accuracy, interest and suitability of the content for the children and the match between the plan and the lesson duration. How students addressed a problem was not clear in the students' written responses and, perhaps as a consequence, less attention may have been given to advice about improving problem-solving skills which produced that product.

(This study did not set out to compare the quality of lesson plans prepared in the PBL strand with what was produced before as comparable data from the previous cohort did not exist. As an informal check on skill development, one tutor judged Problems 1 and 6 for scientific accuracy, potential interest, content suitability and duration on a 1 to 9 scale. We emphasise here that these judgements were subjective and not based on objective criteria. Given that, the mean score for the relatively easy Problem 1 was 4.40. For the relatively difficult Problem 6, it was 6.82, an increase that was statistically significant ($p<<0.001$, Wilcoxon test (Cohen & Holliday, 1982)). Bearing in mind the subjective nature of the judgements, this indicates that this tutor felt that skills in these aspects of lesson planning had developed significantly, something with which other tutors expressed agreement.)

Discussion

The evaluation of the PBL element did not compare its effectiveness with what went before because previous cohorts were not assessed. At the same time, the element was only one part of a course. Lesson planning was not practised in other elements but what was done elsewhere may have contributed to any success that the PBL element had. What can be said is that previous cohorts had concerns about planning throughout the course. There is evidence that such concerns were not strong in this cohort for which the only major change was the introduction of PBL. In particular, there was a very large increase in student confidence in planning science lessons which they ascribed to the PBL element (effect size, 2.17; anything greater than 0.8 is considered to be a large effect; see, e.g. Kinnear & Gray, 2005). In addition, most students indicated that they could plan science lessons in what they felt was an acceptable length of time.

Others have reported that students like the opportunity to work collaboratively. This was true of many of the students in this study but not of everyone. Thirteen of the students scored the opportunity at 3 or less out of 9. For these, working in groups was not a particularly attractive feature of the PBL element. Scores for the motivation stimulated by the students' PBL could be described as luke-warm. About one in five of the students (16) scored it at 3 or less out of 9. This is contrary to the enthusiastic reports of several other PBL users and was unexpected. PBL has generally been used, however, in more or less 'mono-cultures', that is, courses which focus on one discipline chosen by the student. Post-graduate, primary school trainees are recruited largely from such mono-cultures and then must learn subjects they may not have chosen voluntarily. In short, their disposition towards science learning can be hesitant and even negative so an overall luke-warm response may be an achievement. At the same time, PBL has often been used to develop *knowledge* at the end of each problem while in this study the main aim was to develop *lesson planning skills*. It may be that a steady development in a skill is not as apparent to a student as would be increases in declarative knowledge and so fails to motivate. The tutors were very positive about the students' motivation but this may simply be a subjective comparison with prior experience. Similarly, the grades awarded for solutions to Problems 1 and 6 suggested an increase in the students' lesson planning skills (effect size, 0.95) but note that the grade judgements were subjective.

For those who wish to introduce use a PBL approach in teacher training or on courses where the emphasis in on skill development, some further observations may be helpful. PBL can allow students to develop their own way of doing things and so recognises that teaching is an idiosyncratic, creative activity (Hilty, 1995; Groves et al., 2005). The tutors were very positive about the course and, given the student responses, the tutor perceptions seem to be generally well-founded. The preparation of the materials was time-consuming and, on reflection, the tutors may have benefited from more preparation for their role. Changing from teacher/expert to what Maudsley (1999) describes as a more shadowy figure is not as easy as might be supposed. In assessing progress, tutors can also be attracted strongly to the quality of the product and neglect to appraise and advise on skill development. Pre-prepared pro-formas reduced the burden of marking for tutors while still providing useful formative feedback for the students. PBL approaches generally call for a ready access to sources of information. Providing resources can be costly. Here, a small grant from the university's teaching development unit bought much of what was needed, supplementing existing materials and computer access to the Internet. There is also a need to recognise that PBL may not meet with the approval of all students. While these were in the minority, they cannot be ignored. What PBL is and what it aims to do needs to be clear to students at the outset and, perhaps, revisited at intervals.

Provision for other learning preferences may also be needed, perhaps through a hybrid approach which offers a mix of problems and direct instruction. There may also be students who make little progress and who need to be identified early so that remedial measures can be applied.

Conclusion

In general, PBL element of the course achieved its main goals. Most students expressed confidence in planning science lessons when their initial knowledge of the topic was weak. At the same time, they did not find science lesson planning too time consuming and many found the PBL to be motivating and they expressed a liking for collaborative work. On this basis, we can recommend that others consider it as a way of working with student teachers. Nevertheless, the approach should not be seen as a panacea. There were students who did not perceive PBL to benefit them or found it to be motivating or who welcomed collaborative learning. This is a reminder that students prefer to learn in different ways and PBL may not be the best way for everyone. PBL is best viewed as one approach amongst several. There may be occasions when a pragmatic mix of approaches is the best way of working, even within a PBL strand.

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